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LARGE SPACE SYSTEMS TECHNOLOGY ELECTRONICS - DATA AND POWER DISTRIBUTION

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Contract NAS8-33432

LSST 1ST ANNUAL TECHNICAL REVIEW

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TECHNOLOGY AREA: ELECTRONIC - DATA & POWER DISTRIBUTION

TASK: CABLES AND CONNECTORS; GROUNDING AND BONDING

OBJECTIVE: DEVELOP THE (TASK) HARDWARE TECHNOLOGY AND MANUFACTURING/USAGE TECHNIQUES REQUIRED TO MEET PLATFORM AND ANTENNA SYSTEM NEEDS IN THE MID-1980'S AND BEYOND.

APPROACH: THE APPROACH TO THIS TECHNOLOGY TASK IS ASSEMBLY TECHNIQUE DEPENDENT, AND WILL THEREFORE BE APPROACHED ON TWO FRONTS.

(1) HARDWARE AND TECHNIQUES ASSOCIATED WITH MANNED-EVA, MACHINE ASSISTED ASSEMBLY.

(2) HARDWARE AND TECHNIQUES ASSOCIATED WITH AUTOMATED ASSEMBLY, i.e., MACHINE AS PRIME WITH MAN CONTROLLING OR AS BACK-UP.

TASK DESCRIPTION:

- ASSESS PLATFORM AND ANTENNA SYSTEM REQUIREMENTS.
- ASSESS STATE-OF-THE-ART HARDWARE.
- INVESTIGATE AND EVALUATE HARDWARE, MANUFACTURING/USAGE TECHNIQUES OF OTHER PROGRAMS.
- DEVELOP CONCEPTS/TECHNIQUES BASED ON KNOWN REQUIREMENTS, AND UPON DEVELOPING STRUCTURAL CONCEPTS AND ASSEMBLY TECHNIQUES.
- DO IN-HOUSE DESIGN EVALUATION AND PREPARE TEST PLANS OF NEW CONCEPT HARDWARE.

TASK STATUS: COMBINED TASK CONTRACT INITIATED WITH THE BOEING COMPANY (NAS8-33432) ON MARCH 30, 1979.

- COMPLETED STATE-OF-ART REVIEW FOR GROUNDING AND BONDING; CABLES AND CONNECTORS
- DEFINED DATA AND POWER SYSTEM DISTRIBUTION REQUIREMENTS
- ESTABLISHED GROUNDING & BONDING; CABLE AND CONNECTOR REQUIREMENTS FOR SPACECRAFT WITH LOAD DEMANDS TO 2.5 MEGAWATTS
- DEVELOPED CONCEPTUAL CONNECTOR DESIGNS FOR MANNED AND AUTOMATICALLY MATED SYSTEMS
- EVALUATED MATERIALS COMPATIBILITY FOR BONDING AND CONNECTORS IN STORAGE AND IN SPACE

ACCOMPLISHMENTS ACHIEVED TO DATE

- REVIEWED LSST REPORTS, SUPPLIER DATA AND ACTIVITIES, AND IN-HOUSE REPORTS ON PRESENT AND PRELIMINARY DESIGNS FOR MANNED AND AUTOMATICALLY ASSEMBLED SPACE POW. SYSTEM CABLES, CONNECTORS, AND GROUNDING AND BONDING MATERIALS AND TECHNIQUES.
- DEVELOPED CONCEPTUAL CONNECTOR DESIGNS FOR AUTOMATICALLY CONNECTED/DISCONNECTED ASSEMBLIES IN SPACE
- ESTABLISHED VOLTAGE CURRENT RATINGS FOR LSST DESIGNS TO 10 MEGAWATTS
- DEVELOPED GROUNDING/BONDING PHILOSOPHY CONCEPTS FOR LSST
- DETERMINED THAT THIN ALUMINUM BUSES ARE BEST FOR HIGH CURRENT HIGH VOLTAGE CONDUCTORS
- CONCLUDED THAT GRAPHITE EPOXY MUST BE COATED TO STOP DETEIORATION AND CHAFFING (DUSTING) IN SPACE AND CANNOT BE USED AS A GROUND RETURN.

#### THRUST FOR NEXT 6 MONTHS PERIOD

- COMPLETE MATERIALS COMPATIBILITY STUDIES
- DEVELOP CONCEPTUAL DESIGNS AND TECHNIQUES - ANALYZE AND EVALUATE USEFULNESS
- DEVELOP ROUTING, TERMINATION METHODS FOR ASSEMBLED DEPLOYMENT BY EVA AND/OR AUTOMATIC/REMOTE COUPLING

#### PUBLICATIONS

- MONTHLY PROGRESS REPORTS
- FINAL REPORT WHICH INCLUDES:  
RECOMMENDED MATERIALS, CABLE AND CONNECTOR DESIGN CONCEPTS, GROUNDING AND BONDING TECHNIQUES, TEST PLAN, AND INFORMATION OF MONTHLY REPORTS.

#### SPACECRAFT POWER LEVELS

#### TYPICAL MISSION POWER REQUIREMENTS (FIGURE 1):

- MISSIONS TO 1980 LESS THAN 5KW
- FUTURE SPACECRAFT POWER DEMANDS STEADILY INCREASING TO 20 MEGAWATTS.  
TYPICAL LOADS - COMMUNICATIONS, EXPERIMENTS, SURVEYS, PHOTOGRAPHY, MINERAL DETECTION, TEMPERATURE SENSING.
- POWER DEMAND SUMMARY CHART (FIGURE 2).
- TYPICAL SPACECRAFT DESIGN:  
FIGURE 3 - ON-ORBIT ASSEMBLY CONCEPT DESIGN FOR COMMUNICATIONS  
FIGURE 4 - COMMUNICATION SATELLITE

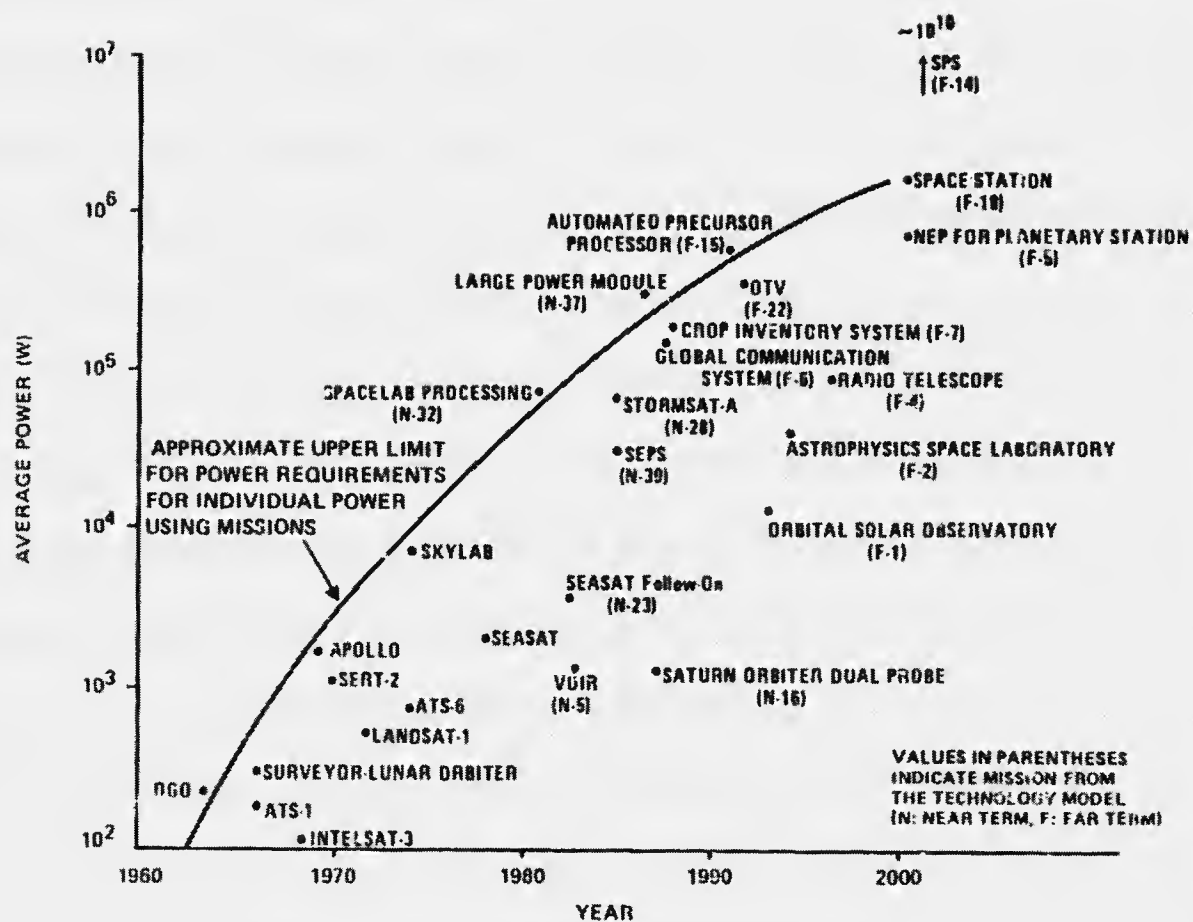


Figure 1.- Mission power requirements.

YEARS	POWER DEMAND - KILOWATTS	
	AVERAGE	MAXIMUM
1980 - 1984	25 - 50	75
1985 - 1990	25 - 100	2,500
1990 - 1995	25 - 750	3,000
1995 - 2000	25 - 2,500	20,000
PAST 2000		TO $10^{10}$ WATTS

Figure 2.- Spacecraft power demands.

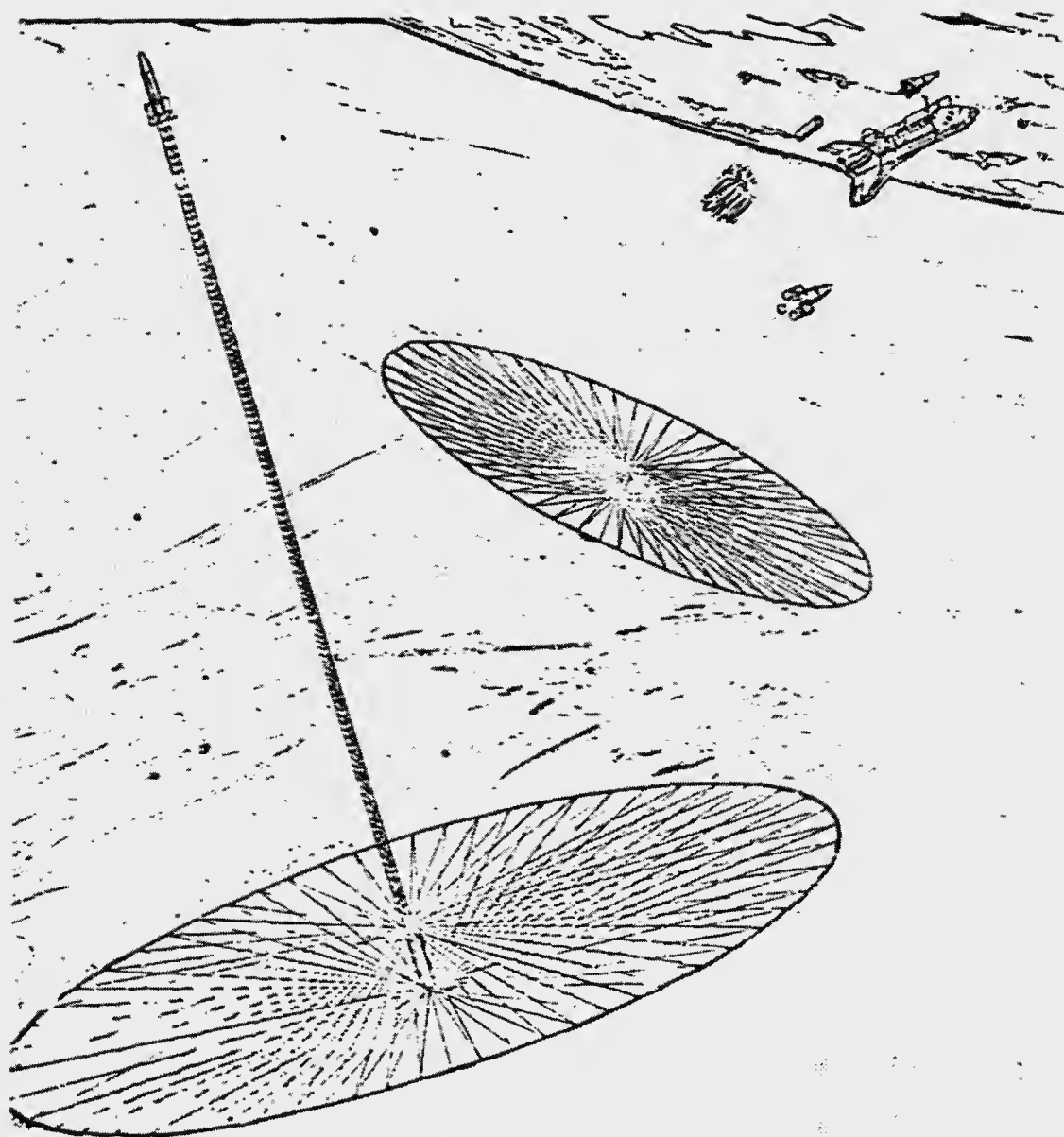


Figure 3.- On-orbit assembly concept design.

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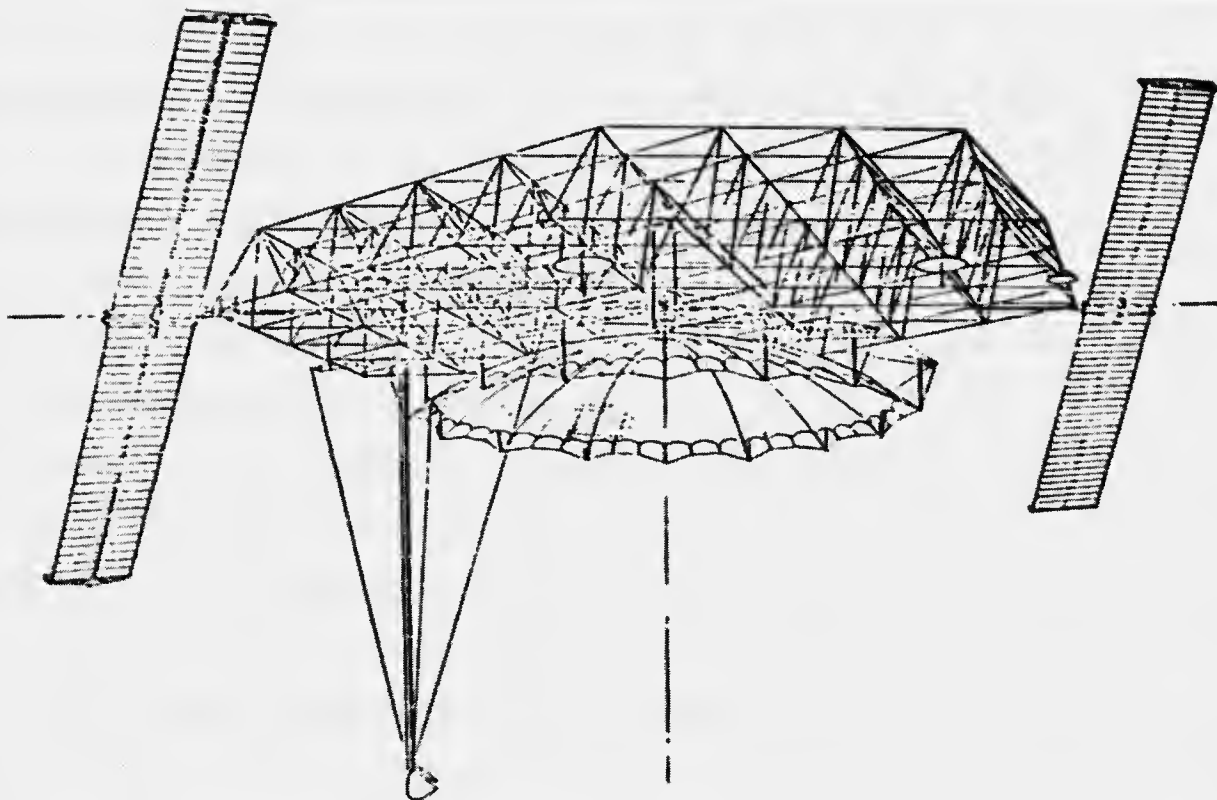


Figure 4.- Dish antenna spacecraft configuration.

#### DISTRIBUTION SYSTEM

- HIGH POWER LSST DISTRIBUTION SYSTEM  
(FIGURE 5):
  - CONVERTS LOW VOLTAGE FROM SOLAR CELLS TO HIGH VOLTAGE SYSTEM
  - DISTRIBUTION BY HIGH VOLTAGE LINES TO LOADS
  - USES COMPUTER TO CONTROL CONVERTER
  - SENSOR SIGNALS TRANSMITTED BY FIBER OPTICS
- GROUNDING AND BONDING CONVENTIONAL AND NEW TECHNOLOGY REQUIREMENTS  
(FIGURES 6 AND 7):
  - LINE VOLTAGES ABOVE 200 VOLTS AND LINE CURRENTS ABOVE 250 AMPERES REQUIRE NEW DESIGN AND MATERIALS TECHNOLOGY; NEW FABRICATING AND INSTALLATION TECHNOLOGY
- CONDUCTOR CONFIGURATIONS CONCEPTS FOR HIGH VOLTAGE AND HIGH CURRENT ARE SHOWN IN  
(FIGURE 8):
  - PROBLEM AREAS INCLUDE:
    - PLASMA AND DEBRIS
    - COOLING
    - INSTALLATION AND CONNECTIONS

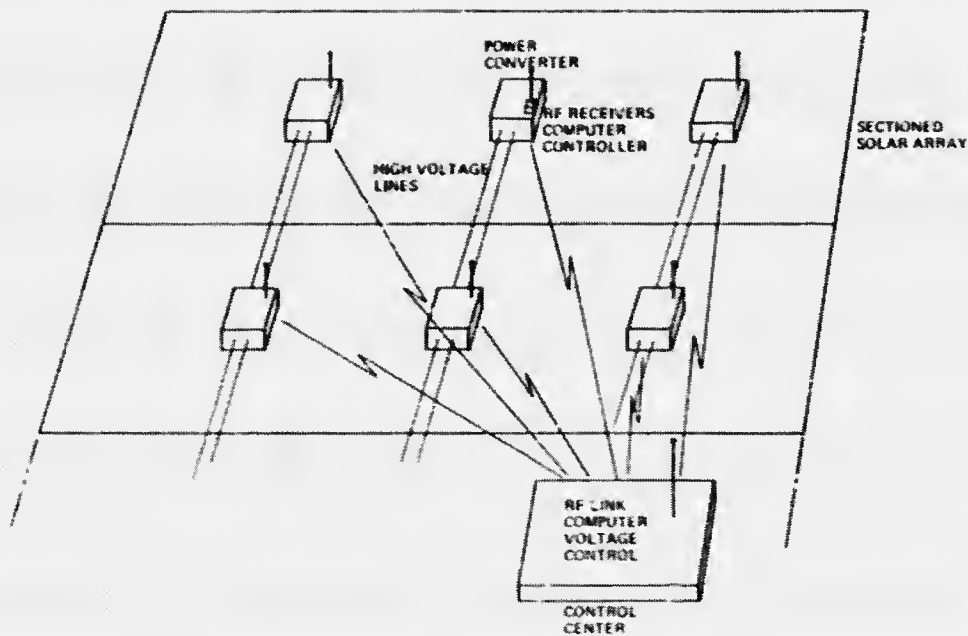


Figure 5.- Spacecraft distribution.

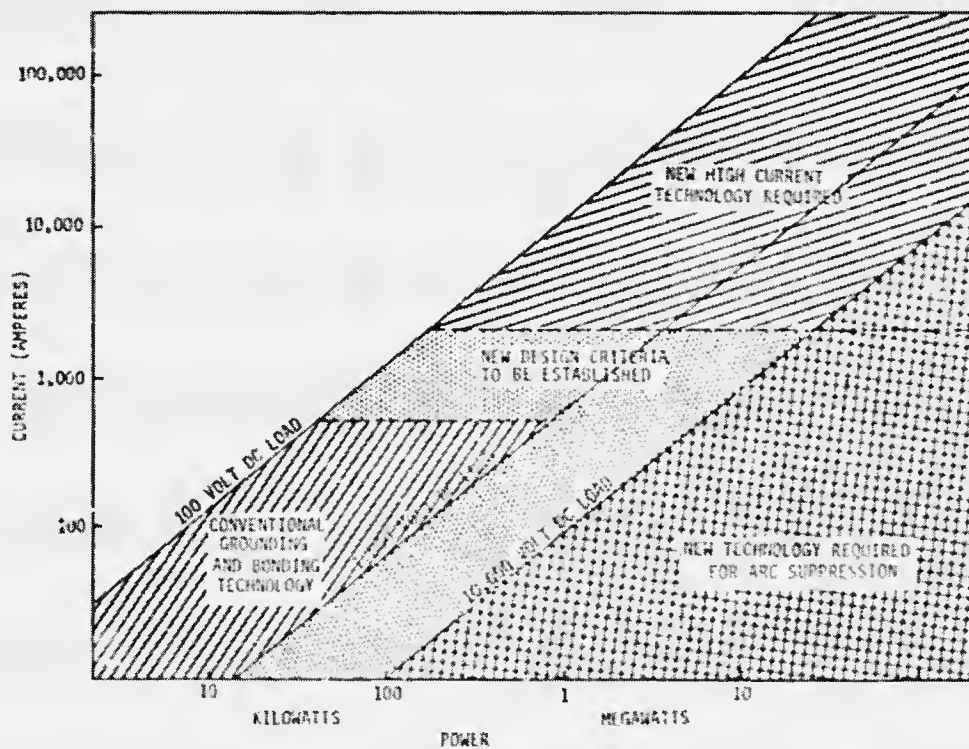


Figure 6.- Bonding and grounding applications for power systems.

POWER LEVEL (MAXIMUM)		VOLTAGE, VOLTS	CURRENT, AMPERES	EQUIPMENT STATUS
25 KW		28 - 200 V	250	<ul style="list-style-type: none"> <li>• SPECIFICATION AND STANDARDS COMPLETE</li> <li>• USE EXISTING TECHNOLOGY</li> </ul>
250 KW		200 - 2,000 V	250	<ul style="list-style-type: none"> <li>• HIGH VOLTAGE SPECIFICATION REQUIRED</li> <li>• NEW INSULATION AND INSTALLATION REQUIREMENTS</li> </ul>
2.5 MW		OVER 2,000 VOLTS	1,000	<ul style="list-style-type: none"> <li>• PLASMA, GAS, AND DEBRIS PROBLEMS</li> <li>• HIGH VOLTAGE, HIGH CURRENT SPECIFICATION AND EQUIPMENT</li> <li>• NEW CONNECTIONS, BONDING, GROUNDING TECHNOLOGY</li> <li>• PLASMA, GAS, AND DEBRIS PROBLEMS</li> </ul>

Figure 7.- Power demand vs. distribution system.

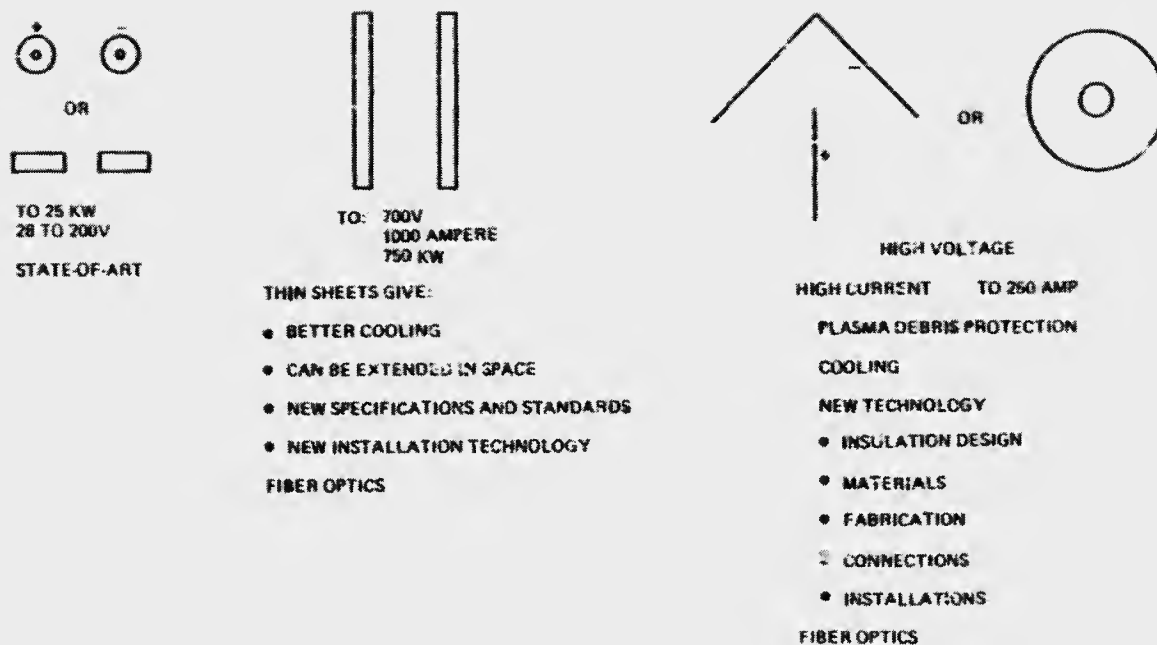


Figure 8.- Conductor configurations.



#### CONNECTOR CONCEPTS

- o ALIGNMENT OF THE MOTHERCRAFT AND DOCKING CHASE CRAFT:  
(FIGURES 9 AND 10) USING RADAR/CAMERA CONTROL WITH ALIGNMENT PINS FOR FINAL ALIGNMENT.
- o CONNECTORS FOR COMMUNICATIONS, SENSORS, AND CONTROL CIRCUITS MAY BE MOUNTED ON A PLATE. THE PLATE PROBE ALIGNMENT PINS MATCH THE SPACECRAFT PINS. THE PLATE IS SPRING LOADED TO APPLY A CONSTANT FORCE ON ALL CONNECTORS DURING MATING AND WHEN DOCKED. (FIGURE 11)
- o FOUR CONNECTOR CONCEPTS: (FIGURES 12 THROUGH 15)
  - FIGURE 12 - MULTIPIN CIRCULAR CONFIGURATION WITH KEYED INSET
  - FIGURE 13 - SINGLE CONDUCTOR HIGH VOLTAGE CONNECTOR - OVER 250 VOLTS
  - FIGURE 14 - BUS BAR CONNECTION WITH SPRING ALIGNMENT FINGERS
  - FIGURE 15 - SIDE VIEW OF BUS BAR CONFIGURATION SHOWING LATCHING MECHANISM
- o A ROUND CONNECTOR LATCHING/UNCOUPLING TOOL:  
(FIGURE 16) TOOL GRIPS THE MATING RING AND TURNS UNTIL THE CONNECTOR IS FULLY MATED BY EITHER THREADS OR LATCHING

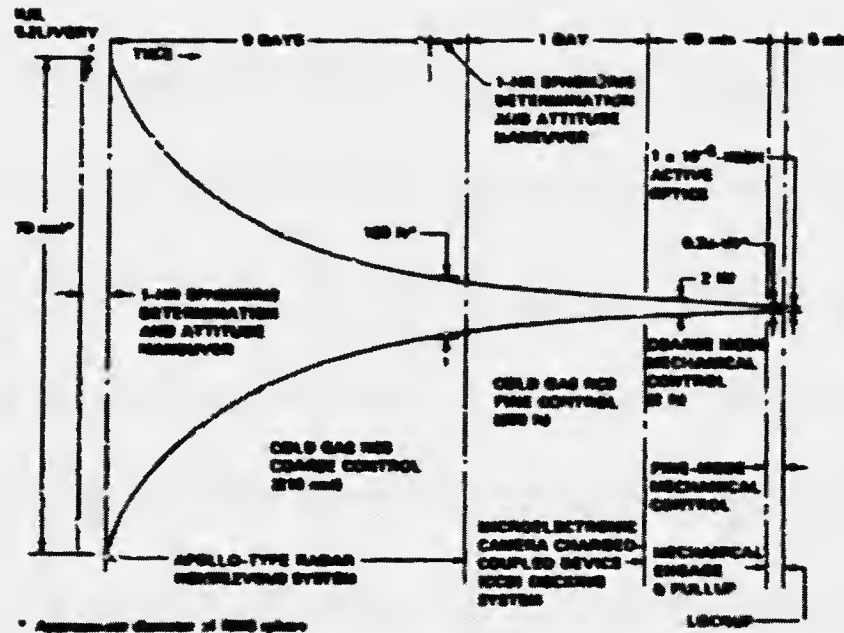


Figure 9.- Docking operation schematic showing use of Apollo-type radar rendezvous system.

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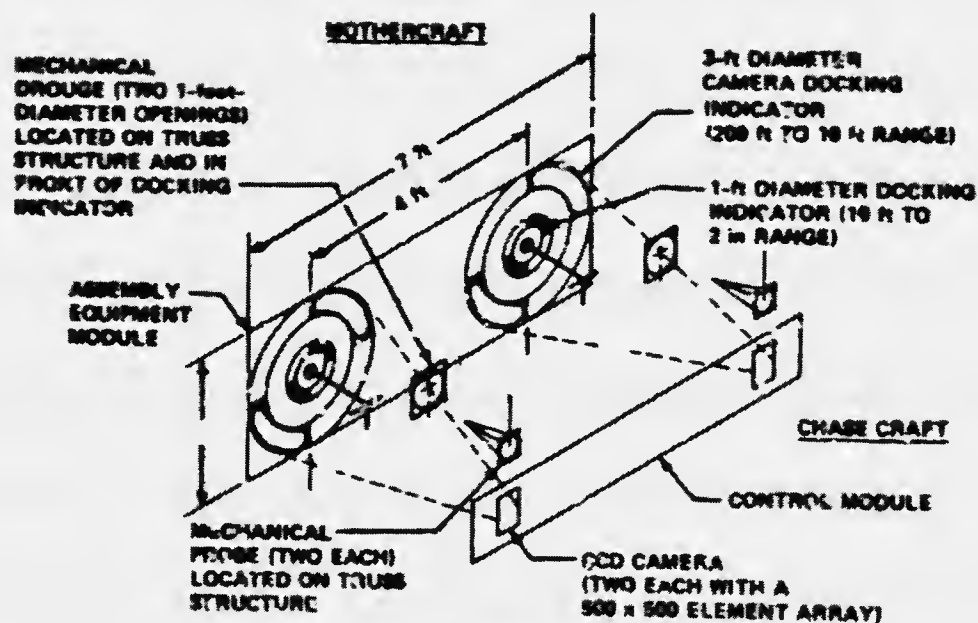


Figure 10.- Microelectronic camera system for mechanical final alignment of drouge to spacecraft during docking.

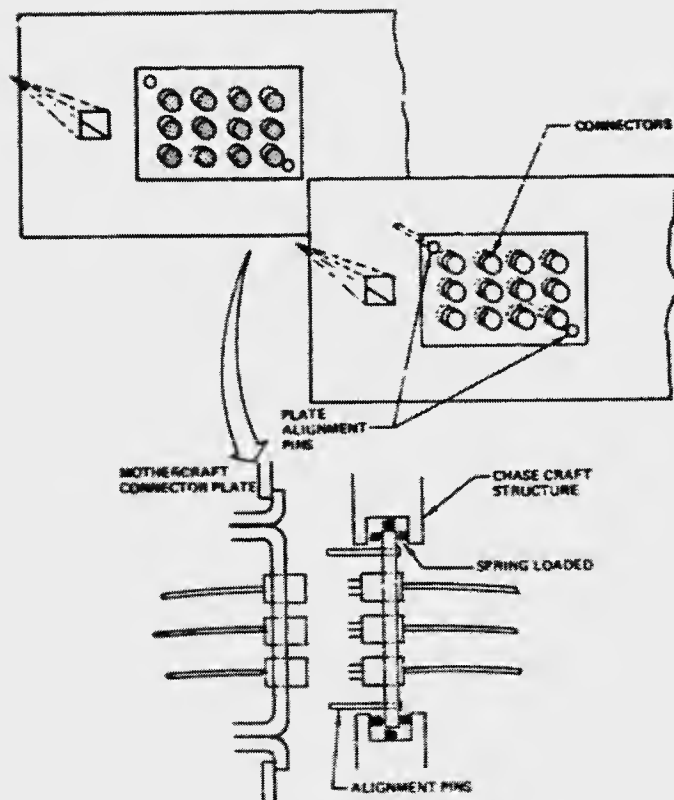


Figure 11.- Connector plate alignment.

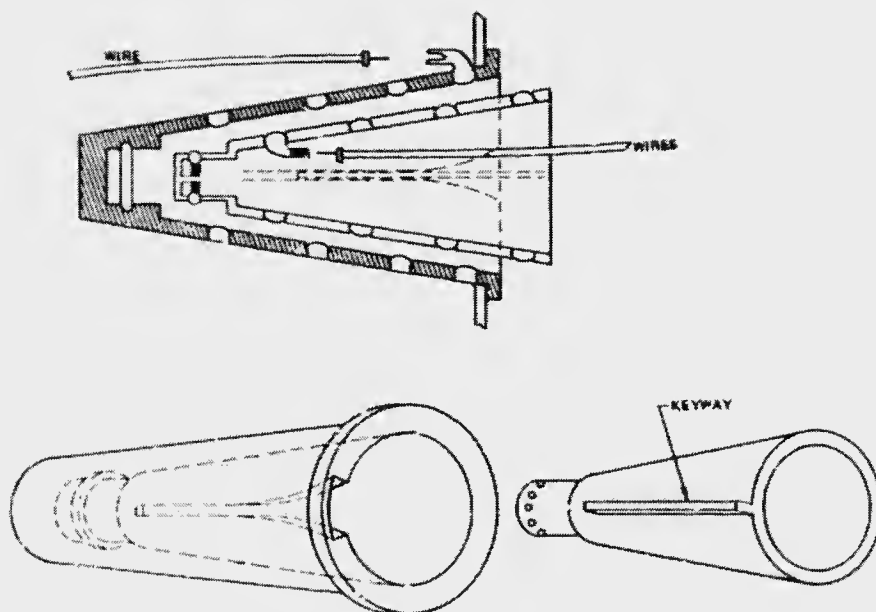


Figure 12.- Cone connector concept.

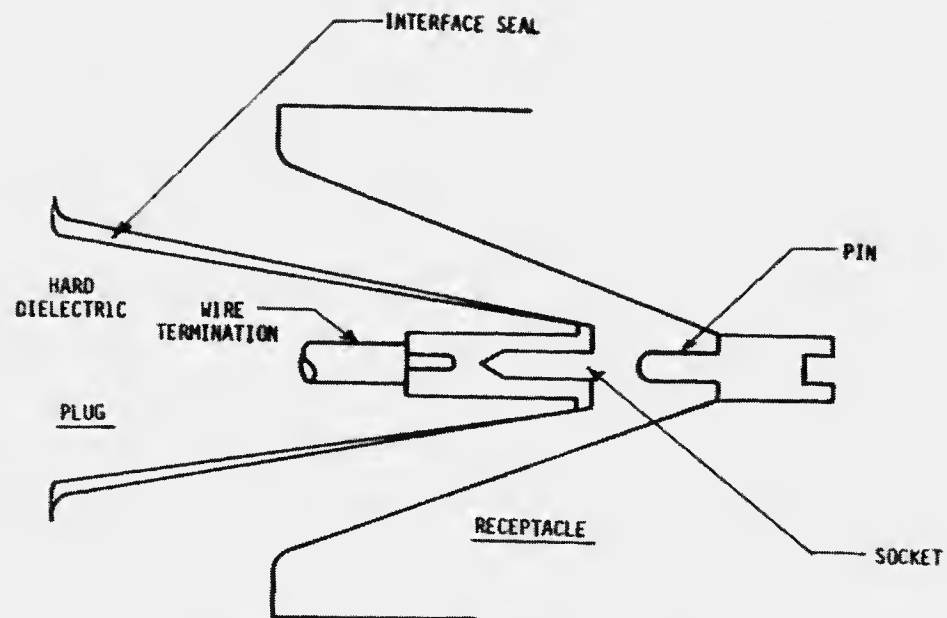


Figure 13.- Cone connector concept.

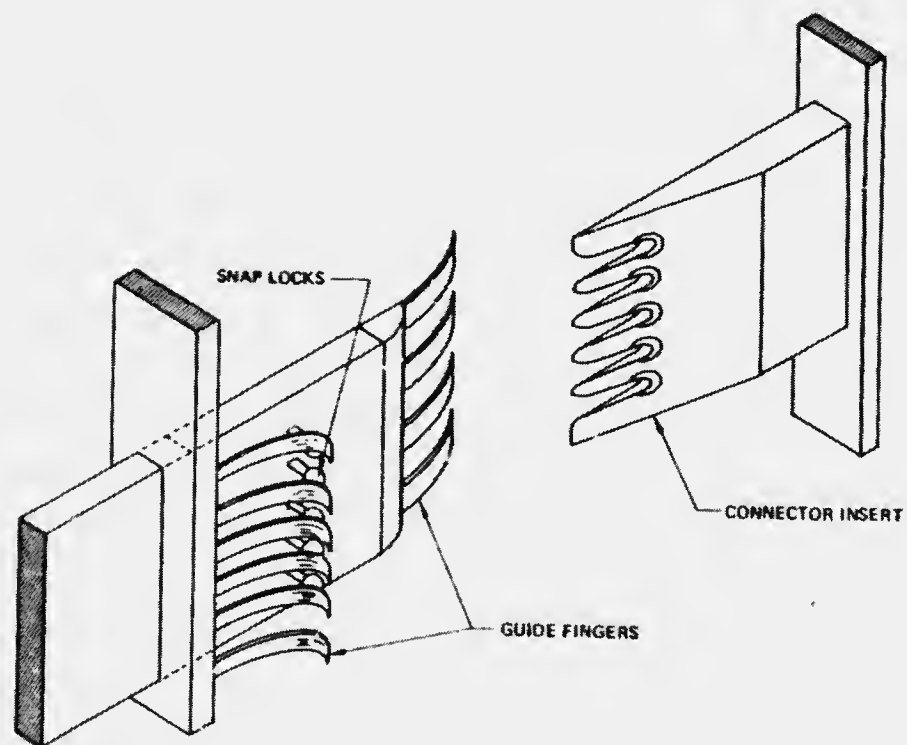


Figure 14.- Rectangular bar connection.

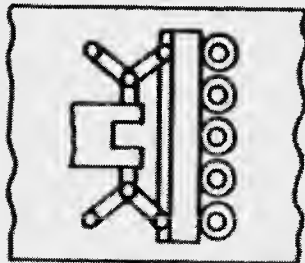
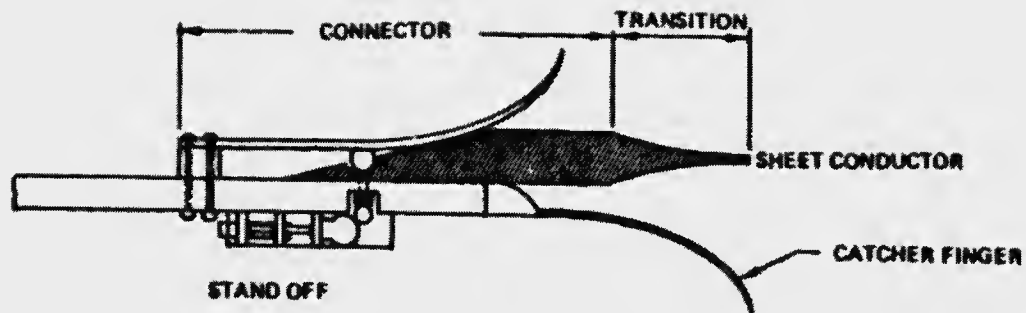


Figure 15.- Sheet metal connector detail.

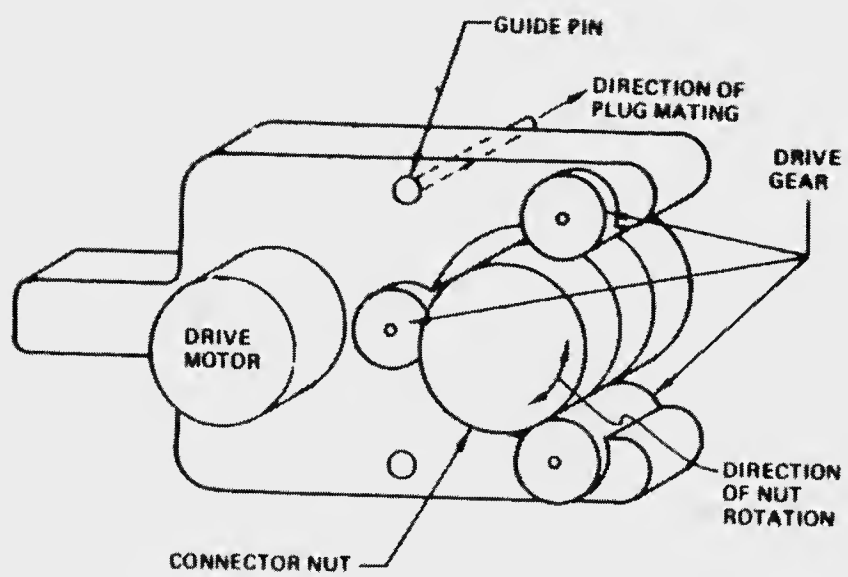


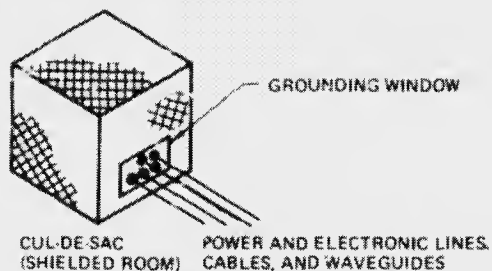
Figure 16.- Connector latching tool.

#### CONNECTOR STATUS

- o LOW VOLTAGE CONNECTORS: 28 TO 250 VOLTS; 1 TO 150 AMPERES
  - 40 M SERIES CONNECTORS -- AVAILABLE
  - MIL-C-38999 CONNECTORS -- AVAILABLE
- o HIGH VOLTAGE OVER 250 VOLTS -- NEW TECHNOLOGY
- o HIGH CURRENT BUS BAR TYPE -- NEW TECHNOLOGY
- o SPECIAL TOOLS AND SHELL DESIGNS REQUIRED FOR COUPLING/UNCOUPLING CONNECTORS IN SPACE
- o NEW CONTACT CONFIGURATIONS REQUIRING 5 TO 70% DECREASE IN MATING FORCE ARE AVAILABLE (HYPERTECC). THESE ARE AVAILABLE FOR PRESENT 40 M AND MIL-C-38999 CONNECTORS

#### GROUNDING DESIGN REQUIREMENT

- GROUND IMPEDANCE SIGNIFICANTLY LOWER THAN THE CIRCUIT COMMON MODE IMPEDANCE
- GROUND PATH VOLTAGE DROP (ENVIRONMENTAL AND CIRCUITS) LOWER THAN CIRCUIT COMMON MODE VOLTAGE SHARING THE SAME GROUND PATH
- GROUNDING TECHNIQUES
  - CUL-DE-SAC -
    - RELIEVES EXTERNAL STRESSES (SHIELD ROOM)
  - GROUNDING WINDOW -
    - SINGLE AREA CONNECTION ALL CABLES AND CONNECTIONS THROUGH A SINGLE PLATE
  - ELECTRONIC SHIELDED COMPARTMENTS -
    - LIMITED TO 15 METER PER LONGEST SIDE. MAY BE SQUARE
  - CUL-DE-SAC CONSTRUCTION OF COPPER OR ALUMINUM
    - ALUMINUM COMPARTMENTS REQUIRE EXTRA HEAVY FASTENER
  - BOND PER MIL-B-5087 OR EQUIVALENT



## BONDING REQUIREMENTS

- POWER RETURN
- VOLTAGE REFERENCE
- ANTENNA COUNTERPOISE
- STATIC BLEED

GRAPHITE EPOXY STRUCTURE SHOULD NOT BE A POWER RETURN. MAGNESIUM DOES NOT BOND WELL - OFTEN USED.

ANTENNA OPERATION BELOW 50 KHz POWER FLOW IN STRUCTURE IS UNACCEPTABLE.

ANTENNA COUNTERPOISE SHOULD BE MADE OF DEDICATED METAL STRUCTURE MIL-8-5087 CLASS R (2.5 MILLIOHM) JOINTS FOR MULTIPLE FASTENERS.

## GRAPHITE - EPOXY

	<u>FIBER</u>	<u>LENGTHWISE</u>	<u>CROSSFIBER</u>
MAX OHMIC VOLTAGE GRADIENT (V/m)	4000	250	4000
MAX OHMIC CURRENT DENSITY (AMPS/m <sup>2</sup> )	10 <sup>8</sup>	4 x 10 <sup>5</sup>	10 <sup>4</sup>
CONDUCTIVITY (MHO/m)	20,000	2000	<20
	(Holzschuh)		(Scruggs)

- GRAPHITE JOINTS MUST BE TAILORED TO CURRENT RISE (RATE)

LOW RESISTANCE AT LOW CURRENT LEVELS REQUIRES MORE FIBER CONTACT THAN FOR HIGH CURRENT.

#### COEFFICIENT OF LINEAR EXPANSION

MATERIAL	PER UNIT EXPANSION
GRAPHITE EPOXY	1.0
ALUMINUM	45
MAGNESIUM	45
STEEL	20
TITANIUM	18

#### MATERIALS COMPATIBILITY REQUIREMENTS

- THERMAL COEFFICIENTS OF EXPANSION
- GALVANIC POTENTIAL
- SUSCEPTIBILITY TO MOISTURE AND SPACE RADIATION
- VULNERABILITY TO ENVIRONMENTAL ELECTROMAGNETIC HAZARDS



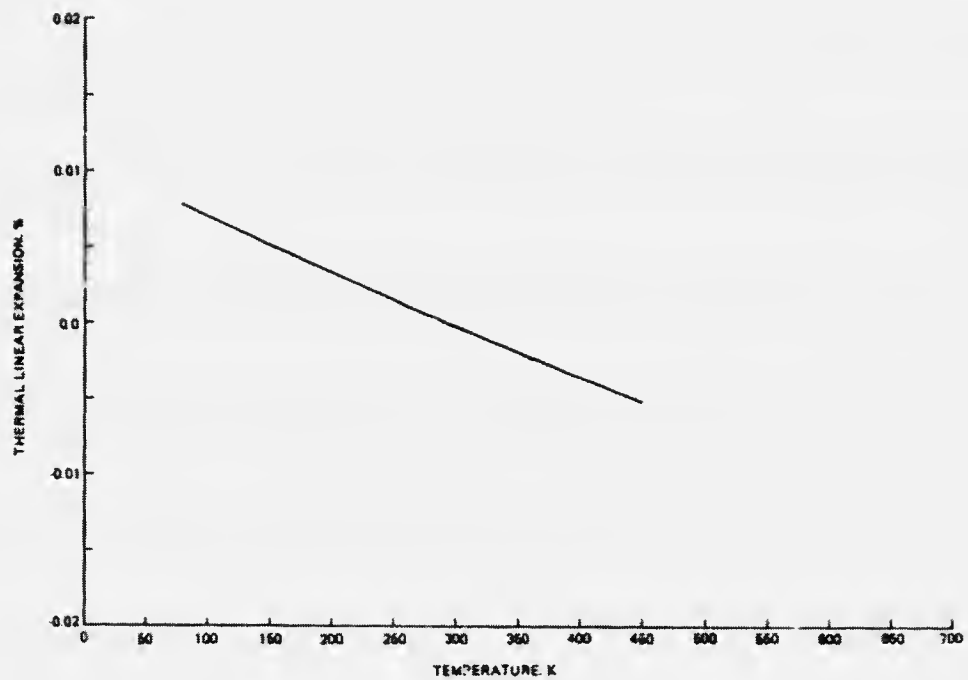


Figure 17.- Longitudinal thermal linear expansion of high strength graphite fiber epoxy composites.

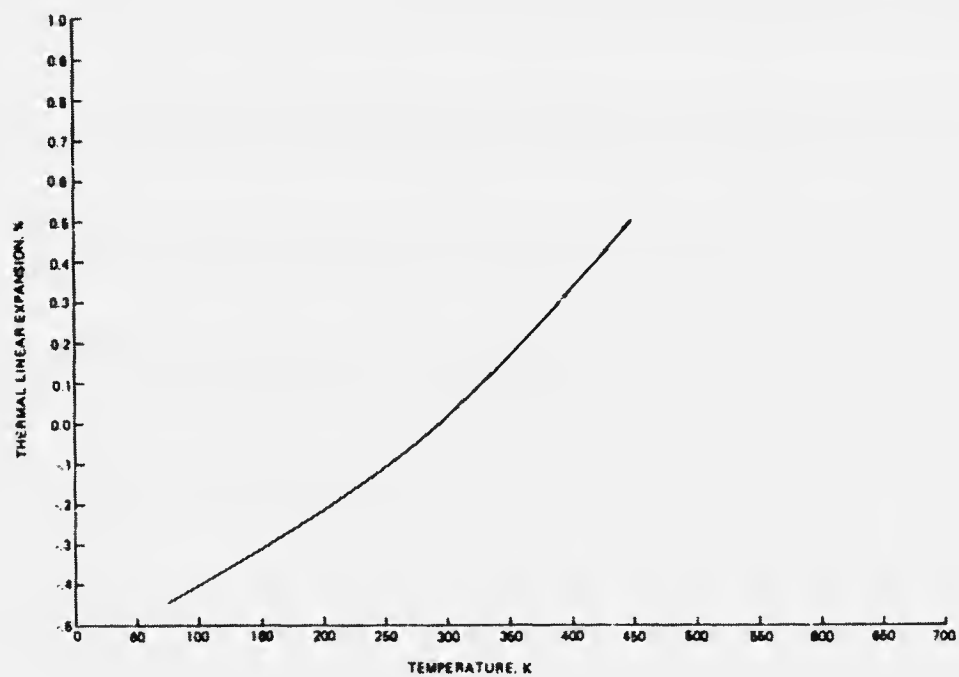


Figure 18.- Transverse thermal linear expansion of high strength graphite fiber epoxy composites.

## GALVANIC POTENTIAL

GRAPHITE AND ALUMINUM CAN PEACH 2 VOLTS IN MOISTURE. MUST BE SEALED AND MOISTURE-FREE DURING STORAGE OR PAINTED WITH NON-CONDUCTING FINISHES.

## MOISTURE AND SPACE RADIATION

- EPOXY HAS A STRONG AFFINITY TO WATER DURING STORAGE.
- COATINGS WILL SEAL IN MOISTURE AND INCREASE OUTGASSING IN SPACE.
- SPACE RADIATION DETERIORATES EXPOSED EPOXY. COATINGS ARE REQUIRED TO PRESERVE STRUCTURAL AND BONDING INTEGRITY OF THE MATERIALS.

## RECOMMENDATIONS

IN DESIGNS WHERE GRAPHITE/EPOXY IS COUPLED WITH MATERIALS, FOLLOW THE RULES BELOW:

### METAL GROUPING

I	II	III	IV
MAGNESIUM AND MAGNESIUM ALLOYS	ALUMINUM ALLOYS, CADMIUM AND ZINC PLATE	LEAD, TIN, BARE IRON AND CARBON OR LOW ALLOY STEELS	CRES, NICKEL, AND COBALT BASED ALLOYS, TITANIUM, COPPER, BRASS, CHROME PLATE

- DO NOT COUPLE GROUP I, II, OR III METALS DIRECTLY TO GRAPHITE/EPOXY .
- WHEN GROUP I, II, OR III METALS ARE WITHIN 3 INCHES OF GRAPHITE/EPOXY AND CONNECTED BY AN ELECTRICALLY CONDUCTIVE PATH THROUGH OTHER STRUCTURES, ISOLATE\* THE GRAPHITE/EPOXY SURFACES AND EDGES.
- TITANIUM, CRES (A286 OR 300 SERIES STAINLESS STEEL), NICKEL, AND COBALT-BASED ALLOYS MAY BE COUPLED TO GRAPHITE/EPOXY STRUCTURES. WHEN OTHER GROUP IV METALS ARE COUPLED, ISOLATE\* THE GRAPHITE/EPOXY SURFACES AND EDGES.

#### \* ISOLATION SYSTEM:

- ONE LAYER OF TEDLAR; OR TYPE 120 GLASS FABRIC WITH A COMPATIBLE RESIN; OR FINISH.

#### PARTICULATE PROBLEM

THERE ARE THREE SOURCES OF PARTICULATE DEBRIS CONTAMINATION FOR LARGE STRUCTURE SPACECRAFT. THEY ARE THE EARTH ENVIRONMENT, SPACE ENVIRONMENT AND THE SPACECRAFT ITSELF. PARTICULATES STRIKING THE SPACECRAFT SURFACE, AT HIGH VELOCITY, MAY BREAK LOOSE MUCH MORE MATERIAL TO ADD TO THE PROBLEM.

THE ELECTRIC FIELDS AROUND A HIGH VOLTAGE SURFACE (CONDUCTOR) WILL ACT AS A PERCIPITATOR COLLECTING THE DEPRIS FROM SEVERAL METERS OF SURFACE AREA AS SHOWN IN FIGURE 19. AS THE PARTICULATE ACCUMULATES "BEADS OF PEARLS" WILL FORM TOWARD THE SURFACES OF OPPOSITE POLARITY. IN TIME ARCING WILL TAKE PLACE THROUGH THESE "BEADS OF PEARLS" AS SHOWN IN FIGURE 20.

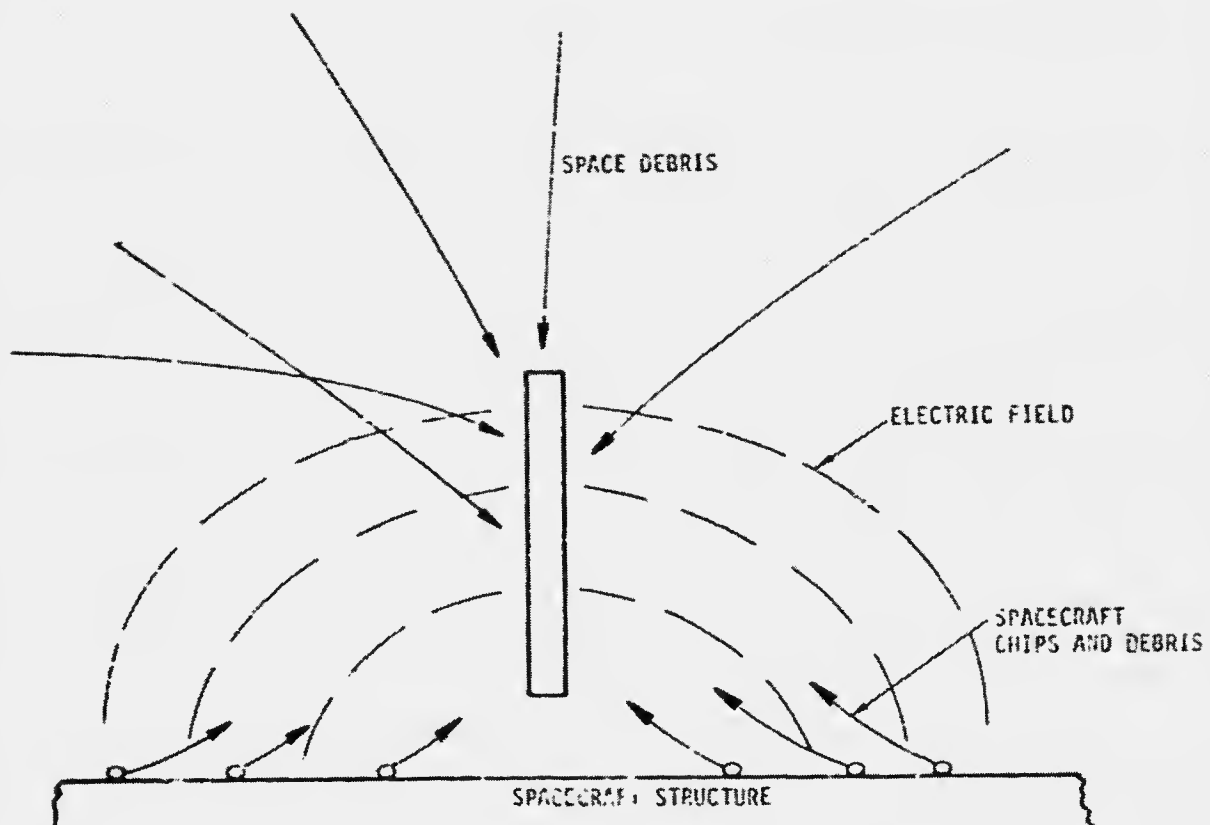


Figure 19.- Particulate damage.

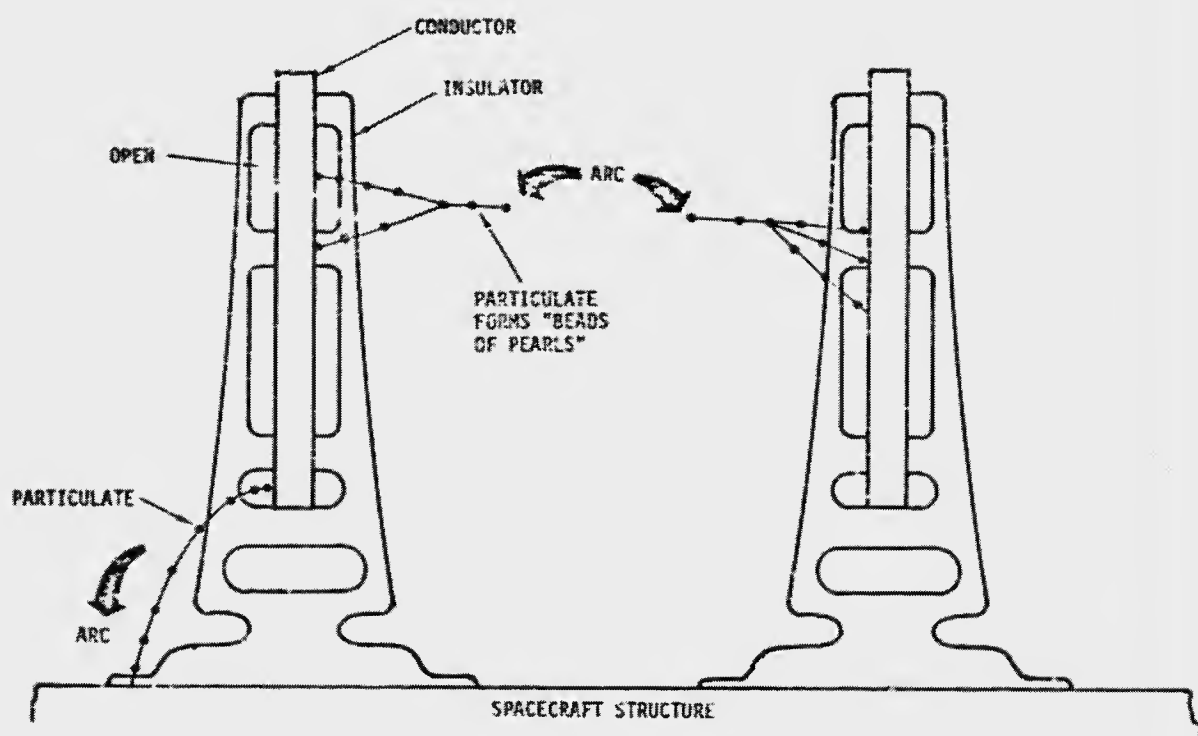


Figure 20.- Particulate damage.